UNIVERSITI PUTRA MALAYSIA

SOFTWARE DEVELOPMENT OF ACTIVE POWER FILTER DESIGN FOR HARMONIC MITIGATION

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By

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June 2002

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The development of design automation tools for a power electronic circuit has received a great deal of attention in the last two decades. To provide an optimum solution for each power electronics application demands the selection of the most appropriate power electronic devices, power circuit and control philosophy. For a certain applications, it must be decided which power circuit topology and which power semiconductor with which control strategy is best suited for it. Their design and fabrication require extensive knowledge and sophistication that must be continually updates as the technologies improve. Considerable engineering effort and knowledge are required to take a power circuit from a laboratory prototype to a finished product. Other than being an expert in areas as diverse as thermal design, circuit and system packaging, circuit protection, and safety and electromagnetic interference regulations.

With such a highly demanding expertise required of power electronic circuits' designers and with such rapid advancements in the field of circuit topology and semiconductor devices it is difficult for designers to come up with an optimum circuit and the right device within a short time. If a design aid system that embraces all the elements of power circuitry design of products may be achieved in a short time and quality of the products will be kept on a consistent high level.

The developed system is named AFDAS (Active Filter Design Aid System). The system characterized as an intermediate object-oriented system connecting the user with a network of different specialized software packages, without the assumption of the user familiarity with these packages. The implementation includes developing a data base circuits library, generation of formatted files to be used as input streams with the design packages, writing an interface program for each kind of these software's, and managing the data flow timing and dependency among them. In this thesis the circuit topology database development based on PSPICE is presented with examples of single-phase active filter resistive load and three-phase active filter resistive load.

Abstrak tesis yang dikemukakan Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

PEMBANGUNAN PERISIAN REKABENTUK PENAPIS AKTIF KUASA UNTUK MENGURANGKAN HARMONIK

Oleh

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Pembangunan perkakasan rekabentuk automasi untuk litar elektronik kuasa telah mendapat banyak perhatian dalam tempoh dua dekad terakhir. Bagi menyediakan penyelesaian optimum bagi setiap keperluan aplikasi elektronik kuasa, pemilihan kebanyakan peranti-peranti elektronik kuasa, litar kuasa dan falsafah kawalan yan bersesuaian perlu dibuat. Untuk sesetengah aplikasi, penentuan mesti dibuat terhadap topologi litar kuasa dan semikonduktor kuasa dengan strategi kawalan yang bersesuaian dengannya. Rekabentuk dan pengilangan perkakasan ini memerlukan pengetahuan dan pemahaman mendalam yang mesti dikemaskini sesuai dengan peningkatan teknologi. Pertimbangan pengetahuan dan keupayaan kejuruteraan diperlukan untuk mengambil litar daripada prototaip makmal kepada produk akhir selain daripada menjadi pakar dalam bidang yang terbahagi kepada rekabentuk haba, pembungkusan litar dan sistem, perlindungan litar, dan peraturan-peraturan keselamatan dan gangguan elektromagnetik.

Dengan peningkatan keperluan kepakaran yang tinggi terhadap perekabentuk-perekabentuk litar elektronik kuasa dan dengan kemajuan yang pantas dalam topologi litar dan peranti-peranti semikonduktor, adalah sukar bagi mereka untuk menampilkan litar yang optimum dan peranti yang betul dalam tempoh yang singkat. Jika dengan satu sistem bantuan rekabentuk yang merangkumi semua elemen litar, rekabentuk produk boleh dicapai dalam tempoh singkat dan kualiti produk-produk akan dikekalkan pada tahap tinggi yang konsisten.

Sistem yang dibangunkan dinamakan sebagai SBRPA (Sistem Bantuan Rekabentuk Penapis Aktif). Sistem ini dikategorikan sebagai sistem berorientasikan objek menyambungkan pengguna dengan rangkaian pakej-pakej perisian tanpa menganggap kebiasaan pengguna dengan pakej-pakej ini. Pelaksanaan ini melibatkan pembangunan pangkalan data sumber litar, penjanaan fail-fail berformat untuk digunakan sebagai aliran masukan dengan pakej-pakej rekabentuk, penulisan program antara muka untuk setiap jenis perisisan ini, dan pengurusan pemasaan dan penggantungan aliran data antara perisisan-peroisisan ini. Dalam tesis ini, pembangunan pangkalan data litar berdasarakan kepada PSPICE dibentangkan dengan contoh-contoh penapis aktif satu fasa beban rintangan dan penapis turas tiga fasa beban rintangan.

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I certify that an Examination Committee met on 20 June 2002 to conduct the final examination of Ramdan Emhemmed Rajab on his Master of Science thesis entitled "Software Development of Active Power Filter Design for Harmonic Mitigation" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for equations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(RAMADAN EMHEMMED RAJAB)

Date: 26 June 2002

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LIST OF ABBREVIATIONS

AF	Active filter
AC	Alternating Current
ADD	Addition
BASIC	Beginner's al-purpose symbolic Instruction Code
BJT	Bipolar Junction Transistor
CAD	Computer Aided Design
COBOL	Common basic oriented language
DC	Direct Current
ERC	Electrical Rules Check
GUI	Graphical User Interface
h	Harmonic order
HZ	Hertz (cycle per second)
IDE	Integrated Development Environment
IEEE	Institute of Electric and Electronic Engineering
IGBT	Insulated gate bipolar transistor
I_h	Magnitude of individual harmonic components (rms amps)
I_L	Maximum demand load current (rms amps)
I_{sc}	Short circuit current at the point of common coupling
MOSFET	Metal oxide semiconductor field effect transistor
MUL	Multiplication
PC	Personal Computer
PCC	Point of Common Coupling
PF	Passive Filter
PROBE	Graphical waveform Analyser
PSPICE	Simulation package
PWM	Pulse Width Modulation

RAD	Rapid Application Development
RMS	Root Mean Square
RSS	The Root of the Sum of the Squares
TDD	Total Demand Distortion
THD	Total Harmonic Distortion
V	General Symbol for the Voltage Measured in (Volt)
V_h	Magnitude of individual harmonic components (rms volts)
V_n	Nominal system fundamental frequency voltage (rms volt)
AFDAS	Active Filter Design Aid System
CDB	Circuit Data Base
AI	Artificial Intelligence
HAES	Harmonics Analysis Expert System
MOOD	Methodology of Object-Oriented Design
APF	Active Power Filter

CHAPTER I

INTRODUCTION

Harmonics in Power Systems

The cause of harmonic distortion is the presence of non-linear loads in distribution system. Since the load current at a non-linear load is non-sinusoidal, this current results in a non-sinusoidal bus voltage due to the non-zero driving point bus impedance at the load. Consequently harmonic frequencies are injected into the system causing the distortion of supply waveform.

Early studies on power system harmonic distortions pointed to saturable elements like transformers as the main source of non-linearity. However with the advent of solid-state switching employing diodes and thyristors and the increasing use of domestic electrical appliances such as television receivers, florescent lamps and light dimmers, harmonic distortions has become an important area of study.

Analysis of harmonics is done by treating the non-linear devices as a generator of harmonics, which cause a harmonic voltage drop across the power system impedance and produces amplitude modulations of the power system voltage. The effects of harmonics on consumers and power systems has been the subject of many extensive studies and amongst others they have been found to cause:

- malfunctioning of microprocessor-based equipment,
- overheating in neutral conductors, transformers, or induction motors,

- deterioration or failure of power factor correction capacitors,
- erroneous operation of breakers and relays, and
- pronounced magnetic fields near transformers and switchgear.

Utility systems are usually a minor source of power quality problems. Studies show that 65 to 85 percent of power quality problems originate in customers homes or businesses. Problems with grounding, neutrals, wiring, and harmonics generated by equipment, and other sources can interfere with or damage other equipment in the facility.

Distorted Waveforms and Harmonics

Ideally the voltages and currents generated and distributed in an electrical power system should be sinusoidal at 50 cycle per second. However since the inception of alternating current power system, distortion on the voltage and current waveforms have been observed. Generally a non-sinusoidal periodic waveform consists of:

a) a fundamental wave- of the lowest frequency, f = 50 Hz. In the case of power system voltage, f = 50Hz, and
b) component waves of higher frequencies which are integral multiples of the fundamental, i.e.; 2f, 3f, and 4f etc.

The fundamental frequency f is referred to as the first harmonic whilst the component frequencies 2f, 3f, etc. are referred to as the second and third harmonic and so forth respectively.

Introduction of Expert System

Expert systems are now being used successfully in many disciplines and practical environments in different parts of the world. The current trends is that they will be used in large numbers and greater varieties of applications. Confronted by the ever-increasing range of academic and commercial products, potential users of expert system technology require systematic and reliable techniques for evaluating expert systems. Also, as the size and complexity of expert systems increase, the task faced by the designers and developers to produce quality systems become more challenging. This situation is further compounded by the lack of detailed and precise requirement specifications of expert systems especially those which involve a number of human experts specialized in different functions of the expert system. Hence compared with other types of systems, expert systems by nature stand in a special need of rigorous and systematic evaluation of their performance. For potential users, this process can be conducted on a finished product. But for their designers and developers, the evaluation process is a continuous one, which should be carried out throughout the life cycle of the expert systems, which they are building

Research Objectives

The aim of this research work is to develop software of active filter design for harmonic mitigation. To achieve this, the following objectives are accomplished.

- Developing a data base circuits library.
- Generation of formatted files to be used as input streams for the design package.
- Writing an interface program for the system.
- Interface the circuit database (CDB) module with simulator package PSPICE.

Scope of the Work

This thesis consists of five chapters. Chapter I give a brief introduction to harmonics in power systems and expert systems. Chapter II is developed to literature and what others have done in this area. In chapter III the methodology and design of the circuit database is described in details. Chapter IV illustrated the results obtained from the output of the active power filter circuits that was described in this work. Finally, Chapter V concludes the thesis and the recommendations for future work that can be carried out.

CHAPTER II

LITERATURE REVIEW

Power Disturbances

Disturbances are measured by triggering on an abnormality in the voltage or the current Transient voltage may be detected when the magnitude exceeds a specified threshold RMS voltage variations (e.g. sags or interruptions) may be detected when the RMS variations exceeds a specified level (Kazibwe, 1993).

The following terms are used to describe some of the power quality problems in power systems Figure 1 shows some of the power disturbances (Dugan, 1996)

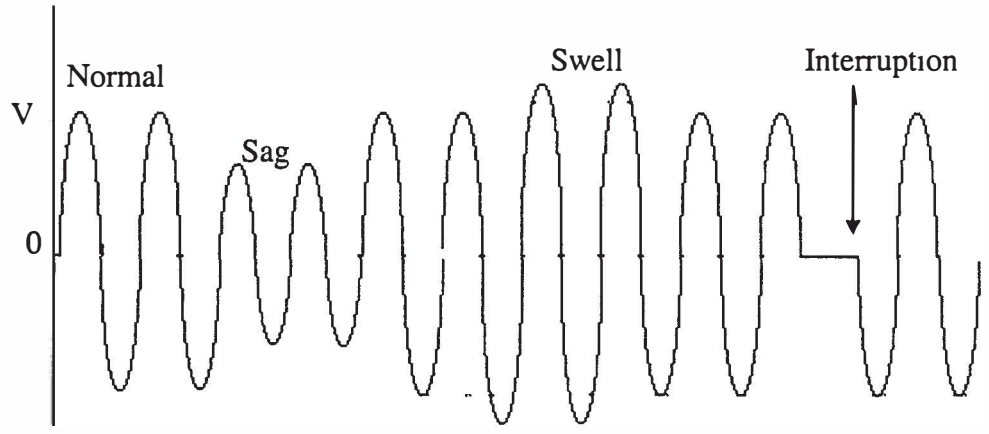

Figure 1:Typical Voltage Disturbances

a) Surge

A surge is defined as sudden increase in voltage of a short-duration (microsecond to millisecond). Also known as impulse or spike. Lightning, power system faults, and the switching of heavy loads cause surges.

b) Voltage sag

Voltage sag is defined as a momentary (less than a few seconds) decrease in voltage outside the normal tolerance. The starting of heavy loads, lightning, and power system faults cause voltage sages.

c) Voltage swell

A voltage swell is a momentary increase in voltage outside the normal tolerance. The turning off of heavy electric equipment causes voltage swells.

d) Undervoltage

Undervoltage is a sustained condition (lasting, more than a few seconds) condition of low voltage outside the normal tolerance. Undervoltages are caused by circuit overloads, power voltage regulation, and international reductions by the utility.